ON PILO-MOTOR NERVES.

By J. N. LANGLEY, M.A., F.R.S. and C. S. SHERRINGTON, M.A., M.B.

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It is well known that in some animals, when they are under the influence of strong emotions, the hair of particular regions of the body becomes erect.

It is obvious that the movement of the hairs must be caused by impulses travelling from the central nervous system, but so far as we know no instance has been recorded in which stimulation of a nerve has produced any effect upon hairs. It has however been found by Jegorow[1] that in the turkey the small feathers of the side of the head assume a ruffled look on stimulation of the cervical sympathetic.

Our enquiries started from independent observations made by one of us on the effect of stimulating the cervical sympathetic in the monkey[2] and by the other on the effect of stimulating the lumbar sympathetic in the cat[3]. Since from the first we talked over our results together, we publish them in a common paper[4].

It will be convenient to have a short name for the nerve-fibres, stimulation of which causes contraction of the erectores pilorum. We shall call them 'pilo-motor' fibres on the analogy of 'vaso-motor' fibres.

The Monkey.

Hairs supplied by the cervical sympathetic.

The Rhœsus monkey (Macacus rhœsus), whether male or female, possesses on the forehead and scalp a somewhat dense crop of short hairs, which, in ordinary circumstances, lie nearly, but not quite, flat; the free ends of the slightly curved hairs being directed backwards. A similar coating of hair clothes the temple, the side of the face in front of the pinna, and the greater part of the cheek. Over the malar prominence

[1] Jegorow. *Du Bois Reymond's Archiv.* 1890. Suppl. p. 33.

[2] *Brit. Med. Journ.* March, 1891.

[3] Demonstrated to Physiol. Society, May 9, 1891.

[4] The experiments recorded here on the monkey have been made by Mr Sherrington, and those on the cat by Mr Langley.

the hair is not so thick and not sloped so obliquely, and the individual hairs are longer and coarser.

On electrical stimulation of the upper end of the divided cervical sympathetic[1] there ensues erection of hair on the forehead, on rather more than the whole of the front half of the scalp, on the temple, cheek, and of the upper part of the whisker. It is in these regions that 'bristling' occurs when the animal is angered or surprised.

The functions of the cervical sympathetic in the monkey are for the most part similar to those well known for the cervical sympathetic of the rabbit, cat, dog, &c. Since however we are not aware of any direct observations recorded of the monkey the effects to be seen on electrical stimulation of that nerve may be given here.

They are: dilatation of the pupil, protrusion of the eyeball, and slight rotation of the eyeball toward the median plane of the head, events which show no noteworthy point of difference from the similar changes occurring in the cat and dog on stimulation of the cervical sympathetic. There is also slight opening of the palpebral aperture, and slight paling of the pinna and of the nostril, but these effects are less than with many animals; there is no withdrawal of the third eyelid, that structure being undeveloped in Macacus.

In addition to the above effects there are three not described for other animals, viz. a slight drawing backward of the pinna of the ear, so that it lies closer to the mastoid region, and projects less from the side of the head; a change in refraction of the media of the eye as measured upon the vessels of the optic disc; and the erection of the hair particularly described in this paper.

The erection of hairs is obtained both with weak and with strong tetanizing currents. It is well obtained also by weak induction shocks of slow rhythm; indeed, as a rule, in the experiments weak induction shocks were employed at the rate of two a second. When the shocks are too weak to be detected on the tongue, the movements of the hairs begin about four seconds after the commencement of the stimulation. The erected position of the hair can be maintained for five minutes and probably for much longer by keeping up the nerve-stimulation. Directly the stimulation is discontinued the erection of the hairs of the scalp begins to subside, and this holds good for both long and short duration of the stimulus.

The effect is unilateral in the sense that, although the area affected is not strictly limited to the median line of the scalp, yet that line is very

[1] All the experiments which are mentioned in this paper were made on anæsthetised animals.

little transgressed, usually less than a centimetre, and less in the fore-part of the scalp than further back behind the vertex. Generally the effect does not reach back so as to involve the occipital region at all.

The pilo-motor fibres of the cervical sympathetic leave the spinal cord by the anterior roots of chiefly the 3rd and 4th thoracic nerves, slightly by the 2nd and 5th also. No effect on the hairs has been produced by stimulation of either the 1st or 6th thoracic nerves in the spinal canal.

The converse of the above effects of stimulation may be observed to follow more or less immediately upon section either of the cervical sympathetic or of the spinal nerve-roots which are the sources of its fibres. The hair lies flatter than normal after section of the nerve or its roots.

The effects in the monkey of section of the cervical sympathetic have not, we believe, been recorded and may be enumerated here, as observed in Macacus rhœsus.

Constriction of the pupil.

Narrowing of the palpebral aperture, chiefly by drooping of the upper lid, but partly by raising of the lower.

Œdema and slight flushing of the skin round the eye, especially round the outer angle and below.

Slight injection and swelling of the caruncle at the inner canthus, and slight "watering" of the eye.

Projection of the pinna from the side of the head, with apparently very perfect retention of its motility. Slight flushing of the pinna, best seen in the engorgement of the veins on its posterior surface.

Slight puckering of the skin of the muzzle.

Flattening and smoothing of the hair in the region already referred to.

Of these effects some last only a few hours, but some persist for a considerable time.

The flattening of the hair caused by section of the sympathetic trunk below the superior cervical ganglion does not pass rapidly away. The muscles of the hairs possess a certain tonus which is lost for several months at least after section of the cervical sympathetic below the sup. ganglion. Thus in a young rhœsus (♀) about $2\frac{1}{2}$ cm. of the left cervical sympathetic, well below the ganglion, was excised. The little wound healed rapidly without any untoward event, and the animal now eighteen weeks after the division of the nerve is still under observation. The hair of the left half of the forehead and of the scalp back to behind the vertex lies flatter and smoother than on the right half. Just in the

same way that the pilo-motor effect of stimulation of the cervical sympathetic transgresses the median line of the scalp by passing about a centimetre beyond it, so the effect of the section of the nerve is not apparent quite up to the median line, falling a little short of it especially in the more posterior region of the scalp. This of course points to the tonus of the erectores pilorum of those hairs which are situate near the median line being maintained by the influence of both right and left sympathetic trunks, and so long as one of the two nerves remains intact the tonus is not seriously affected by the destruction of the other. Whether this is applicable to each individual hair, or is only true of the crop of hair as a whole, is a further question. The paralysed hairs are of the same length or certainly not longer than the normal ones of the opposite side, but the hairs of the eyebrow on the side corresponding to the section of the sympathetic are twice as long as those of the opposite eyebrow. When in the animal we are now considering anger or surprise is induced the hair bristles upon the forehead, whisker, &c. of the right side only. This is important since it indicates that there are no other pilo-motor fibres to these hairs other than those running in the sympathetic. Erection of the hair on the scalp can sometimes be caused by rubbing the skin under the axilla; in the monkey with sected cervical sympathetic this reflex is only obtainable on the right side.

In addition it may be mentioned that the left pinna still projects from the side of the head more than does the right, indeed the difference between the two appears as marked now as it was immediately after the section of the nerves, and the palpebral opening of the left side is notably smaller than that of the right. The left pupil is still smaller than the right, the difference being more marked in a dim than in a bright light, and the difference is quite unmistakably less now than it was at the end of the first week after the operation. This diminution of the effect accords with the fact that after section of the 2nd and 3rd thoracic roots of the right side in a Rhœsus in which the left cervical sympathetic had been divided ten days previously the right pupil was observed to be little more than half the diameter of the left under equal moderate illumination of both.

In Rhœsus we have never been able to detect any movement of the large isolated hairs, probably "tactile," which grow on the lips, especially on the upper.

A further step was to determine whether the pilo-motor fibres in their course from the spinal cord to the hairs are connected with nerve-cells, and if so in what ganglion or ganglia.

To this end the nicotin method of Langley and Dickinson was employed[1].

Appended are details of the experiment.

Experiment.

Strong Macacus rhœsus, young, ♀. Anæsthesia maintained by A. C. E. mixture.

Cervical sympathetic exposed on left side 5 cm. below the ganglion; ligatured and cut through.

Superior cervical ganglion exposed on left side, loose ligature placed under extreme upper end of ganglion.

Induction shocks were used for excitation at the rate of twice a second.

Greatest distance in centimetres of the secondary from the primary coil, at which stimulation of

	Sympathetic in neck produced		Distal end of ganglion	
Time	Erection of hairs	Dilation of pupil	Erection of hairs	Dilation of pupil
2.30	30·5	30·5	30·5	30·5
2.55	30·0	30·0	30	30
2.57	Inject 10 mgs.[2] of nicotin (in 4 p.c. solution) into anterior tarsal vein.			
3.7	30·0	30·0	30	30
3.17	28·5	23·0	29	29
	Inject 10 mgs. of nicotin into tarsal vein.			
3.27	29	No effect at 20	29	29
	Inject 10 mgs. of nicotin.			
3.37	27·5	13	27·5	28
	Inject 20 mgs. of nicotin.			
3.50	16·0	11	24·0	25
	Inject 20 mgs. of nicotin.			
4.7	No effect at 5	No effect at 5	22·0	22

No great stress is to be laid upon the details of a single experiment, but there is one point we may note in the above. According to Langley[3] for

[1] *Proc. Roy. Soc.* Vol. xlvi., p. 424, 1889.

[2] The nicotin used was dark coloured and so probably was of less than its nominal strength.

[3] This *Journ.* xi. p. 144, 1890.

the submaxillary ganglion of the dog and cat, and Langley and Dickinson[1] for the superior cervical ganglion of the cat and rabbit, the nerve-cells of the ganglion in the course of nerve-fibres of different kinds, though coexisting in one and the same ganglion, are not all paralysed at the same time. In the monkey it appears from the experiment given that those cells in the superior cervical ganglion which belong to the pupillo-dilator nerve-fibres are earlier affected by doses of nicotin than are those belonging to the pilo-motor nerve-fibres.

Thus, after a certain amount of nicotin had been injected, stimulation of the sympathetic in the neck had no effect on the hair, although stimulation of the upper end of the superior cervical ganglion still caused erection. The pilo-motor fibres, then, are connected with nerve-cells in the superior cervical ganglion. Only one experiment of the kind was made since the result as far as the main point was concerned appeared to be decisive. The inference is further borne out by the results of the following experiment in which degeneration of the cervical sympathetic was employed as a method of examination after the manner introduced by Waller.

EXPERIMENT.

Mac. rhœsus, young, ♀. Two cm. of the lower part of the left cervical sympathetic were excised, and ten days later, the small wound having completely healed in the interval, both cervical sympathetics were exposed, the left up to the superior ganglion. To the naked eye the left trunk appeared normal. The lower end of the piece above the excision had been turned upward at the time of the excision, and was found to be in the position in which it had been left; it was *not* imbedded in scar tissue even at its extreme end. The length of trunk available for stimulation below the superior ganglion was about 3 cm. Stimulation of the right trunk gave the usual effects on skin with induced currents, when the secondary coil was distant 32 cm. from the primary. By stimulation of the left trunk no effects could be obtained even with the secondary at 5 cm., and although series of shocks at various rates were tried. But stimulation of the top of the left superior ganglion gave results as under:

secondary at 12 cm. from primary gave no effect on pupil, at 11 cm. good effect.
„ „ 14 cm. „ „ „ „ „ „ hair, „ 13 cm. „ „ .

It seems therefore that in the monkey ten days after section of the sympathetic trunk in the neck, the part of the nerve above the section loses its excitability as far as up to the superior ganglion for hair and

[1] *Proc. Roy. Soc.* XLVII. p. 379, 1890.

pupil effects at least, but that as regards those effects the nerve at and beyond the ganglion is still irritable. In short the nerve-fibres for the hair (and pupil) degenerate up to, but not beyond, the superior cervical ganglion, and they are there connected with cells of the ganglion.

That section of nerves and subsequent examination for degenerated fibres could be used as a general method of tracing the course of nerves, was first stated by Waller, in *Phil. Trans.* Pt. II. 1850. And Waller, partly in combination with Budge, showed in cats and dogs that on section of the cervical sympathetic, (1) the part between the place of section and the superior cervical ganglion alone degenerated, (2) stimulation of sympathetic beyond the ganglion caused dilatation of the pupil and withdrawal of the nictitating membrane in the normal manner[1]. Schiff confirmed the degeneration of the upper end of the cervical sympathetic after section of the nerve[2]. Waller (1853) also found that the vaso-constrictor nerves for the ear behaved in the same way as the dilators for the pupil. Similar facts were shown by Langley for the sympathetic fibres causing secretion and vaso-constriction in the sub-maxillary gland of the cat[3], and by Bradford for the sympathetic secretory fibres for the sub-maxillary gland of the cat[4].

Hairs of the buttock, thigh and tail.

In Rhœsus the outer aspect of the thigh, and the buttock above the callosity, and also the root of the tail possess a crop of hair much longer than is that of the scalp. This hair is erected on stimulation of the lumbar sympathetic trunk in the abdomen.

Stimulation of the lower end of the trunk after section between the 7th lumbar and 1st sacral ganglia causes erection of hairs on the side of the tail for about two inches of its length, and of the hairs on the buttock especially above and to the outer side of the callosity, the area being conterminous, or very nearly so, on the thigh with the elevated skin which becomes flushed at the period of rut.

Stimulation of the lower end of the nerve after section between the 6th and 7th lumbar ganglia causes erection of the hair over an area corresponding with the posterior part of somewhat less than the middle

[1] Cf. Budge and Waller, *Zeitsch. f. wiss. Zool.* III. p. 347, 1851, and statement as to Priority of Discovery by Waller, *Nouvelle méthode anatomique pour l'investigation du systême nerveux, Pt.* I. *étant une lettre envoyée à l'académie des sciences de Paris le* 23 *Nov.* 1851. Bonn, 1852.

[2] *Arch. f. physiol. Heilkunde,* II. p. 145, 1852; cp. also *Lehrbuch d. Physiol.* I. p. 119, 1858—59.

[3] This *Journal,* Vol. VI. p. 87, 1885.

[4] This *Journal,* Vol. IX. p. 302, 1888.

third of the outer aspect of the thigh, and is fairly coextensive with the area of 'sexual' skin.

Stimulation of the lower end of the trunk after section between the 5th and 6th lumbar ganglia causes erection of the hair over a strip-shaped area which extends from the mid-line of the back laterally across the ilium and downwards along the upper two-thirds of the postero-external aspect of the thigh. The strip is about 4 cm. wide, and at its anterior edge is on a level with the crista ilii.

The pilo-motor fibres in the lower lumbar sympathetic of Rhœsus may be traced back into the roots of the 12th thoracic, and the 1st, 2nd and 3rd lumbar nerves in the spinal canal. From lumbar nerve-roots below the 3rd no evidence of them has been obtained.

The erection of the hairs of the buttock, thigh and tail differs from that of the hair of the scalp in that it persists long after cessation of the stimulation of the nerve. It has at present only been looked for in young female specimens of Rhœsus, and it is possible that in the female and male the phenomenon may present differences.

Cat.

The following account is given by Darwin in *The Expression of the Emotions*, p. 128, of the mode in which terror shows itself in cats. They "stand at full height, and arch their backs in a well-known and ridiculous fashion. They spit, hiss, or growl. The hair over the whole body, and especially on the tail, becomes erect. In the instances observed by me the basal part of the tail was held upright, the terminal part being thrown on one side;...The ears are drawn back, and the teeth exposed."

Of these various actions, one only, viz. the erection of the hairs, is produced by stimulating the sympathetic. The parts of the body in which an erection of hairs can be produced by stimulation of the sympathetic are (1) a somewhat triangular area on the face between the eye and ear, and (2) a strip beginning on the back of the head and stretching over the cervical thoracic lumbar vertebræ and sacral vertebræ, this strip extends for the most part 2 to $2\frac{1}{2}$ inches from the mid-line on either side; and lastly (3) the dorsal and lateral part of the tail. It is in these parts only that we find erection of hairs in an angry or frightened cat.

The sympathetic nerve-fibres which on stimulation cause a movement of hairs can be traced up to the spinal cord, they arise from 13 or

14 spinal nerves, viz. from the 3rd or 4th thoracic to the 3rd lumbar nerves inclusive.

Of the cervical nerves the lower ones only have been stimulated in these experiments; no pilo-motor fibres are contained in the roots of the 6th, 7th or 8th cervical nerves, nor in the 1st or 2nd thoracic nerves: the 3rd thoracic sometimes contains and sometimes does not contain pilo-motor fibres for the face. No pilo-motor fibres are contained in any nerve-root below the 3rd lumbar. This we think shows conclusively that there are no direct spinal pilo-motor fibres, i.e. no pilo-motor fibres leaving the spinal cord which do not run to and form part of the sympathetic system. The tail perhaps affords the best proof of this, though it can be shown for the other regions in which erection of hairs takes place. The lumbar sympathetic about the level of the 5th lumbar sympathetic ganglion is ligatured and cut; the 2nd and 3rd sacral, the 1st, 2nd and 3rd coccygeal nerves are exposed in the spinal canal, ligatured and cut; on stimulation of the lower end of the lumbar sympathetic, the erection of hairs in the tail is immediate and unmistakable; on stimulation of the nerves in the spinal canal, there is a sharp movement of the tail in its basal, mid or terminal region, according to the nerve stimulated, but no trace of erection of the hairs.

The hairs when once erected return very slowly to their normal position, so that it is advisable to smooth the hairs down before each nerve stimulation.

Hairs supplied by the cervical sympathetic.

On stimulation of the cervical sympathetic, movement of hairs can be seen in two regions, (1) the face area already mentioned between the eye and ear, (2) on the back of the head and over the cervical vertebræ[1].

(1) In the face area, the movement of the hairs is less than in the lower half of the back and in the tail. Besides the proper erection of the hairs, there is a contraction of the underlying platysma; in the posterior part of the area, the skin is drawn together in a direction transverse to the axis of the body, whilst in the anterior narrower part near the eye, the direction of contraction is more antero-posteriorly. In one cat, an area almost exactly corresponding to that in which erection of hairs occurs, formed on either side, an almost bald patch; this, it

[1] Occasionally the cervical sympathetic has little or no pilo-motor effect.

seemed possible, might be due to some pathological change in the cervical sympathetic; but no evidence could be obtained of this. Stimulation of the nerve produced the usual effects.

(2) The area of the back of the head and neck: this area begins about in a line between the ears, laterally it does not stretch up to the ears, in the neck the strip broadens soon extending about two inches on either side of the median line. On stimulating one cervical sympathetic the effect is unilateral except that the median line is overpassed by about a centimetre. The hairs in this region also have a less range of movement than those of the lower half of the back and of the tail.

Posteriorly the strip reaches nearly to the thorax; it was a considerable surprise to find this area affected by the cervical sympathetic and superior cervical ganglion, since this ganglion is not known to send fibres to the lower part of the neck.

The pilo-motor fibres of the cervical sympathetic arise from the 4th, 5th, 6th, 7th thoracic nerves, and sometimes also from the 3rd. The 7th thoracic has only a slight effect; as a rule the maximum effect in the face area is obtained from a nerve higher than that which first gives the maximum effect on the neck area.

On section of the cervical sympathetic on one side, the effects on the head and neck of stimulating the spinal nerve-roots on that side is abolished.

Ten milligrams of nicotin injected into the jugular vein annuls for a time the effect of stimulating the cervical sympathetic, but does not annul the effect of stimulating the nerve-fibres beyond the ganglion; i.e. the pilo-motor fibres end in the cells of the superior cervical ganglion.

Nerve supply of hairs of the back and of the tail.

Anteriorly the region we are considering is continuous with the neck region already spoken off. It is not clear which is the highest spinal nerve sending pilo-motor fibres to this region, but the highest of which distinct evidence was obtained is the 7th. Below this all the nerves to the 3rd lumbar inclusive give off pilo-motor fibres. As has been said above, no nerve-root below the 3rd lumbar affects the hairs.

Each spinal nerve causes the hairs to stand up on a considerable portion of skin, the strip affected is in the back about 10 centimetres long. Taking any two successive nerves, it is found that the strip innervated by the lower nerve begins and ends about 2 centimetres more

posteriorly than the upper one; thus the greater part of the innervated areas are common to the two nerves; and any one small spot of the skin is innervated from four or five spinal nerves.

The method by which this is effected is seen on tracing the nerves from the spinal cord outwards. If several successive sympathetic ganglia are isolated except for their grey rami; i.e. if the trunk of the sympathetic above and below each ganglion, and the white ramus, if it has one, be cut; stimulation of the portion of the sympathetic above and attached to the ganglion, or of the ganglion itself or of its grey ramus, causes a movement of hairs which is of much less extent than that caused by stimulating a spinal nerve. The observations on this point have been chiefly made with the 2nd, 3rd, 4th, 5th sympathetic lumbar ganglia; each of these supplies the hairs of a small region of the back about 2 centimetres long, these areas are successive, they overlap very little if at all; the areas taken together correspond fairly closely with the area found in other experiments to be innervated by the 12th thoracic nerve. The general plan of arrangement is then that each spinal nerve sends out fibres in four—and possibly more[1]—successive grey rami; and taking the spinal nerves in succession each sends fibres to one less grey ramus anteriorly and to one more posteriorly than the nerve above it.

The erection of hairs is not equally great throughout the whole of the strip innervated by a spinal nerve; the maximum is usually rather below the mid-part of the strip; that is to say the spinal nerve sends less fibres to the uppermost and lowermost than to the median grey rami with which it is connected.

We have spoken of a spinal nerve as sending out fibres in the grey rami; the nerve-cells of the ganglion are however on the course of these fibres. That, though easily shown for the nerves of the back, we will speak of in connection with the tail.

The spinal nerves which supply nerve-fibres to the erectores pilorum of the tail are the 2nd and 3rd lumbar and not infrequently the 1st lumbar also. We have already said that the areas of the back supplied by successive spinal nerves largely overlap. The same is the case and to a greater extent with those which supply the muscles of the hairs on the tail.

The 1st lumbar nerve supplies a strip, the anterior extremity of which is 8 to 10 centimetres above the root of the tail, the posterior extremity

[1] To determine the exact relation between each spinal nerve and the sympathetic ganglia requires further experiments.

may be at the root of the tail or it may be a short distance down the tail.

The 2nd lumbar nerve supplies about $\frac{1}{2}$ to $\frac{2}{3}$ of the tail, and may also supply a small part of the skin of the back.

The 3rd lumbar supplies the whole of the tail and may also supply the hairs for a short distance above the root of the tail.

The hairs on the dorsal surface and on the side of the tail are erected on nerve stimulation; those on the ventral surface are not. It is interesting that in most cases stimulation of the 2nd and 3rd lumbar nerve on one side causes erection of hair on *both* sides of the tail. This bilateral action usually occurs also on stimulating the lower lumbar sympathetic on one side. The pilo-motor fibres for the tail run down the sympathetic chain, and become connected with nerve-cells chiefly in the 1st coccygeal ganglion. For whilst normally stimulation of the sympathetic between the 4th and 5th lumbar sympathetic ganglia causes erection of the hairs along the whole length of the tail; after 10 to 15 milligrams of nicotin have been injected into a vein, such stimulation is entirely ineffective; nor does stimulation of any part of the lumbar sympathetic chain produce an effect, but on stimulating the 1st coccygeal ganglion the hairs of the tail from root to tip are erected; and on stimulation of the 3rd sacral ganglion or its ramus there is some, though less, erection of hairs in the root half of the tail.

Summary and Conclusion.

The hairs of the monkey, cat, and probably of all animals in which horripilation occurs under the influence of strong emotion as fear or anger, may be erected by stimulation of nerve-fibres which issue from the spinal cord and pass through the sympathetic nervous system. These hairs have no direct spinal supply.

The nerve-fibres which cause a movement of hairs by acting on the erector muscles, we call pilo-motor nerve-fibres.

Monkey. In Macacus rhœsus the pilo-motor nerve-fibres for the face and head issue from the spinal cord in the anterior roots of the 3rd and 4th and to a less extent of the 2nd and 5th thoracic nerves; they run to the sympathetic chain, ascend the cervical sympathetic, and become connected with nerve-cells in the superior cervical ganglion.

The parts of the head affected are, the forehead, the front half of the scalp, the temple, the cheek and the upper part of the whisker; on stimulating one sympathetic the effect is chiefly on the same side, but

stretches a short distance over the median line; on cessation of the stimulation, the hairs rapidly return to their normal position.

On section of the cervical sympathetic, the hairs of the above mentioned parts lie flatter than normal, and remain so for many weeks. In a monkey in which the cervical sympathetic has been cut on one side, fear and anger cause the hairs of the normal side of the head only to stand up.

Stimulation of the cervical sympathetic besides producing to a greater or less degree effects like those which are known to occur in other animals causes a slight drawing backwards of the pinna of the ear, so that it projects less from the side of the head and a change in the refraction of the media of the eye as measured upon the vessels of the optic disc.

Pilo-motor nerve-fibres for the buttock, thigh and tail issue from the spinal cord in the roots of the 12th thoracic, 1st, 2nd and 3rd lumbar nerves; they pass into the lumbo-sacral sympathetic chain and descend it. They are finally distributed to the skin of the upper part of the buttock, the back of the thigh nearly as far as the knee, and to the root of the tail. Their distribution is fairly co-extensive with the area of sexual skin in the adult female (Macacus rhœsus).

Cat. Pilo-motor fibres leave the spinal cord to run to the sympathetic chain in each nerve from the 4th thoracic to the 3rd lumbar; sometimes also from the 3rd thoracic nerve. The roots of no other spinal nerve from the 4th lumbar downwards contain pilo-motor fibres.

Fibres from the 3rd or 4th thoracic to the 7th thoracic nerve inclusive ascend in the cervical sympathetic, become connected with nerve-cells in the superior cervical ganglion, and supply the hairs of a region between the ear and eye, and of a strip of skin beginning at the back of the head and extending down the back of the neck. These fibres are either not present or are not functional in all cats.

Pilo-motor fibres from about the 7th thoracic to the 3rd lumbar nerve supply the hairs of a strip of the skin of the back, and of the dorsal part of the tail. The strip on the back begins about the upper part of the thorax, stretches to the tail, and extends about 6 centimetres on either side of the median line.

Each of the thoracic spinal nerves supplies a strip of the skin of the back about 10 centimetres long, these strips overlap; taking any two successive nerves, the lower one innervates a strip the beginning and the end of which is about 2 centimetres posterior to the beginning and the end respectively of the strip innervated by the upper one.

Since stimulation of the grey rami of the 2nd, 3rd, 4th, 5th lumbar sympathetic ganglia causes erection of hairs in successive strips of about 2 centimetres only, we conclude that each spinal nerve, the roots of which contain pilo-motor fibres, is connected with four or five sympathetic ganglia and their grey rami.

The 2nd and 3rd lumbar nerves supply pilo-motor fibres to the tail, the former to its basal two-thirds about, the latter to the whole; the 2nd lumbar nerve and possibly the 3rd supplies in addition a small part of the back above the root of the tail. The 1st lumbar nerve chiefly supplies the lower part of the back, but may also supply the hair over the root of the tail.

With any two spinal nerves from the 7th thoracic to the 3rd lumbar inclusive, the position of the *maximum* effect on the hair is more posterior with the lower nerve than with the upper one.

The pilo-motor nerves for the tail are connected with nerve-cells, partly in the 3rd sacral, but chiefly in the 1st coccygeal ganglion.

Stimulation of a spinal nerve or of the sympathetic chain on one side gives mainly unilateral effects on the back,—the hairs for about 1 centimetre only on the opposite side being affected,—but in the tail the effects are usually bilateral.

9.

Sherrington

Degeneration in Spinal Cord

of Dog